

SESSION 1 - AEROPROPULSION MATERIALS RESEARCH

LEWIS MATERIALS RESEARCH AND TECHNOLOGY: AN OVERVIEW

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SUMMARY

The Materials Division at the Lewis Research Center has a long record of contributions to both materials and process technology as well as to the understanding of key high-temperature phenomena. This paper overviews the division staff, facilities, past history, recent progress, and future interests.

INTRODUCTION

The Materials Division at the Lewis Research Center is NASA's focal point for high-temperature materials research aimed at aerospace propulsion and power systems needs (fig. 1). Lewis is NASA's largest materials research group. Currently the staff consists of about 99 civil servants (over 45 percent have earned Ph.D.'s) and 73 National Research Council (NRC) postdoctoral fellows, university consortia members, support service contractors, and industrial guest investigators. Their backgrounds cover all the materials disciplines. Thirty percent of our staff are recent graduates, and this reflects an ongoing commitment to fresh ideas and new talent. Our facilities give us the capability to make, consolidate, and fabricate new materials and to test and analyze them. With the Center's powerful computational capabilities, we can also model, compute, and predict material behavior.

Our job is to create new materials and new understanding in support of NASA's needs and specific materials goals. We then work to transfer the resulting knowledge, technology, and processes to the broad user community.

For those industrial organizations and universities interested in collaboration on research of potential mutual interest, a description of our key facilities can be obtained on request. To help us respond, your request should outline your specific interests.

HISTORICAL MATERIALS DIVISION CONTRIBUTIONS

In the past Lewis has made many contributions to the technology of high-temperature, high-performance materials (fig. 2). In our laboratories, as well as in conjunction with industry, Lewis has fostered the advance of such concepts as

(1) Metal matrix composites. Continuous fiber reinforced metal composites were born at Lewis, and the rule of mixtures was applied to property estimation. More recently, our arc spray monotape fabrication

process (U.S. patent No. 4,518,625; license available) has opened this arena to commercial applications.

(2) Refractory metals and compounds. New W and Mo+Re alloys were discovered at Lewis and then were strengthened by Hf and C additions. We conducted much of the early work on HfC and TaC.

(3) Ceramics. Lewis conducted the first engine tests on brittle cermets, developed early blade root designs for brittle materials, identified the potential of ceramic ball bearings, and generated early data on the oxidation and thermal shock resistance of Si_3N_4 and SiC ceramics indicating their potential for gas turbine service. More recently, a SiC fiber reinforced silicon nitride (U.S. patent No. 4,689,188; license available) was developed which has the best high-temperature strength of any current ceramic composite material.

(4) Coatings. Lewis research resulted in the early identification of NiCrAl and FeCrAl as surface protection systems for superalloys. Our research also produced the first thermal barrier coatings (TBC's) to work in actual gas turbine engine environments and to be tested on blades in engines.

(5) Polymer Composites. PMR-15 was discovered at Lewis, and we supported it through commercial introduction to flight engines.

Today, propulsion system performance limits are pacing aircraft advances. Achievement of viable high thrust-to-weight aircraft; Mach 2 to 6 transport aircraft; very high efficiency/pressure ratio subsonic transport aircraft; vertical, short takeoff and landing aircraft (VSTOL); the National Aerospace Plane (NASP); and other aircraft depends on advances in engine materials. Similarly, in the whole arena of space propulsion and space power, the availability of high-performance materials is controlling advances. Many of the same needs exist for both types of systems. Indeed, as we move toward hypersonic, cryogenic-fueled aircraft and multiple reuse rockets, the temperature, performance, and life demands show significant overlap (fig. 3). One major remaining area of difference is in the environments such materials experience during service.

BASIC RESEARCH

In response to the preceding requirements, the Materials Division is directing its efforts toward advanced high-temperature composites capable of meeting NASA and industry needs for the year 2000 and beyond. Our work involves basic research, focused research, and new concept exploration. The basic studies (about 20 percent of our effort) are aimed at understanding key barrier phenomena. Some of these areas are shown in figure 4. Note that as part of our efforts to mathematically characterize and predict material responses, we have a growing modeling activity supporting our experiments.

Solidification and casting, friction and wear, and chemical synthesis and deposition are major areas of basic interest. This research is thus heavily focused on the basics of processing effects on materials' microstructures and on the understanding of the resultant properties and their degradation during service.

FOCUSED RESEARCH AND TECHNOLOGY

About 65 percent of our effort involves focused research - looking at long range NASA system needs and attacking those issues that either enable or strongly enhance system performance. Such research covers a very broad range of NASA and industry interests (fig. 5). In the area of hypersonic engine structures (and advanced rocket nozzles) we are looking for high-strength/high-conductivity systems such as W fiber/copper composites for cooled applications as well as for high-temperature ceramic composites for hard-to-cool components. Long-life materials for high-speed turbopump blades, bearings, etc. are being sought. Ceramic materials, intermetallic composites, and polymer conductors are all being pursued to provide lightweight, high-performance alternatives to current technology. In the high-temperature superconductor arena we are supporting efforts aimed at NASA-specific applications. To enhance satellite performance and the space station's effectiveness, we are working on improved space lubricants as well as supporting microgravity science and its applications, including the commercial use of space. Here we do focused research on basic microgravity processing issues. In our Microgravity Materials Science Laboratory we work with industry and university investigators to help clarify their ideas and to lay the groundwork for potential space experiments or processing hardware.

SYSTEMS DEVELOPMENT

About 15 percent of our effort supports systems where NASA has a major role in development (fig. 6). For example, our work on the SP-100 (a space nuclear power generation concept) includes materials for lightweight radiators, research that is clarifying the basis for Ge-Si/GaP thermoelectric performance improvements, and high-strength refractory composites for lithium-cooled heat pipes. Our support for the space station includes identifying salts for thermal storage and corrosion-resistant materials for their containment. Our work on advanced chemical propulsion engines is focused on new concepts to extend turbopump and nozzle cycle resistance. In the auto gas turbine program that NASA manages for the Department of Energy (DOE), we have done much to raise the reliability and reproducibility of monolithic ceramics and to characterize factors that currently limit their use. In the NASP program we have a small role but are contributing to intermetallic and ceramic materials development efforts.

NASA recognized the growing relationship between materials availability and system performance limits. So this year a new effort was started. It is called the Advanced High-Temperature Engine Materials Technology Project (fig. 7). This base R&T augmentation will concentrate on accelerating the exploratory and the focused types of our research and will be aimed primarily at eliminating key barriers to consideration of high-temperature composites for engines. With this effort we will be moving to tie together both the materials development and the structural analysis efforts from the start in an attempt to reduce the 12 to 15 year time that new materials normally take to reach system use. We are also trying to create new linkages between ourselves, industry, and the universities. This coordination will benefit U.S. aeropropulsion by concentrating a diversity of views and backgrounds on moving such revolutionary materials forward. Specifically, we expect future advances in ceramics, intermetallics, refractory metals, and polymer composites as well as in the following areas:

- (1) Fibers (improved fiber properties and temperature limits, fiber coating to control interface bonding and reactions as well as new interface characterization methods)
- (2) Composite fabrication (optimizing current processes, but looking for better ways so as to create options to make complex shapes economically in a reliable manner)
- (3) Testing and analysis (new methods and facilities to generate high-temperature property data and to verify the new analytical codes and models to guide layup and fabrication)
- (4) Life and failure analysis (better ways to relate multiphase microstructures to properties and, eventually, properties to component performance)
- (5) Ideas (new ideas to help create a "next generation" basic industry capable of a strong role in world trade)

CONCLUDING REMARKS

We certainly plan to take full advantage of the expected new interactions with industry and the universities to deal with these kinds of problems. We also look at the expanded interactions between materials and structures research as a way to lower the time it takes to validate a new materials idea or analysis method.

STAFF

- 99 CIVIL SERVANTS
 - 85 PROFESSIONAL
 - 45 PERCENT Ph.D.
 - 32 PERCENT M.S.
- IN
 - CERAMICS/CERAMICS ENG.
 - CHEMISTRY/CHEM. ENG.
 - PHYSICS
 - METALLURGY/MET. ENG.
 - MECHANICAL ENG.
- 73 UNIVERSITY CONSORTIA,
NRC POST DOCTORAL FELLOWS,
SUPPORT CONTRACTORS, ETC.

FACILITIES

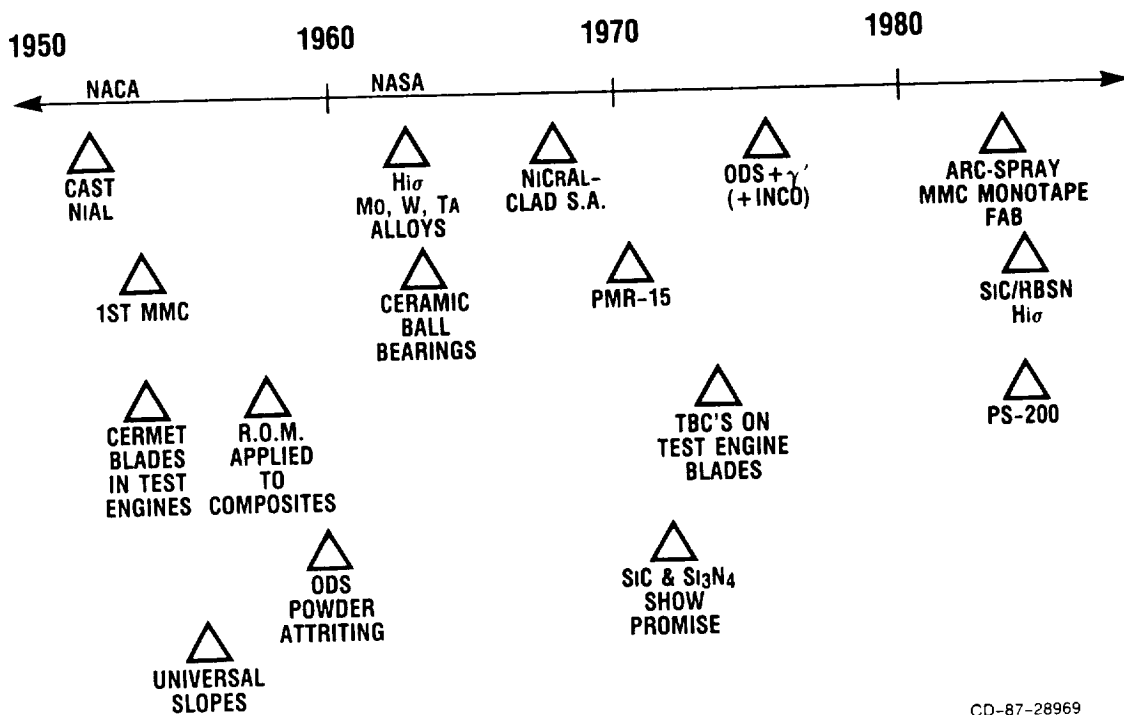
- LABORATORIES IN SEVEN BUILDINGS
- \$40 MILLION IN CAPITAL EQUIPMENT
- TO
 - CONSOLIDATE
 - FABRICATE
 - TEST
 - CHARACTERIZE
 - COMPUTE

MEET NASA'S MATERIALS NEED IN AEROSPACE PROPULSION AND POWER



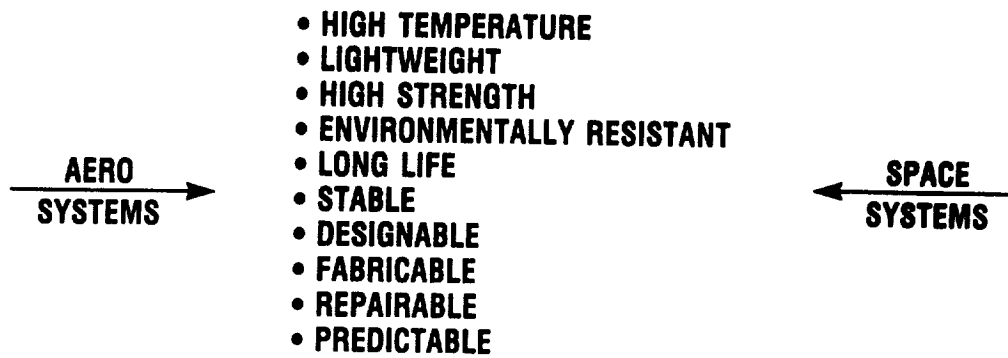
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Figure 1. - Lewis Materials Division.



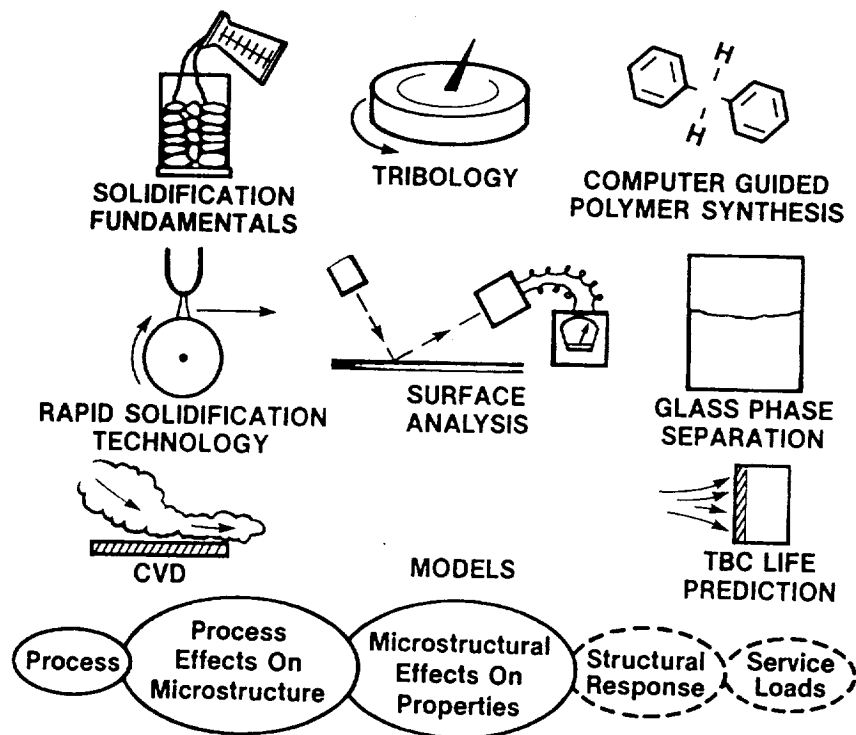
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Figure 2. - Some Materials Division contributions.



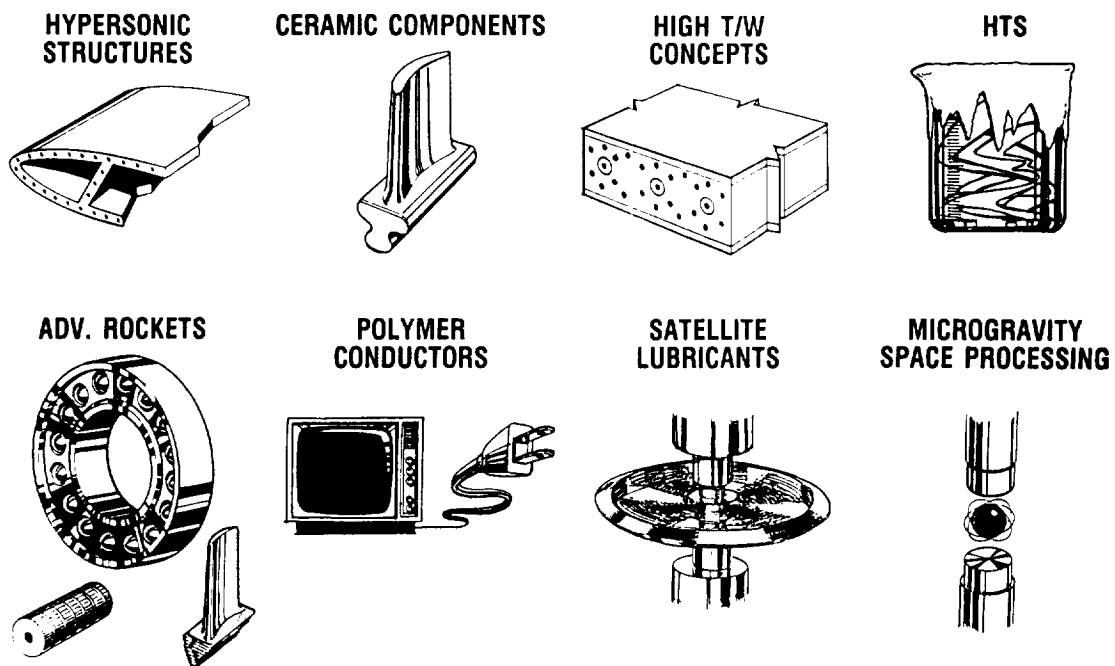
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Figure 3. - Common material needs.



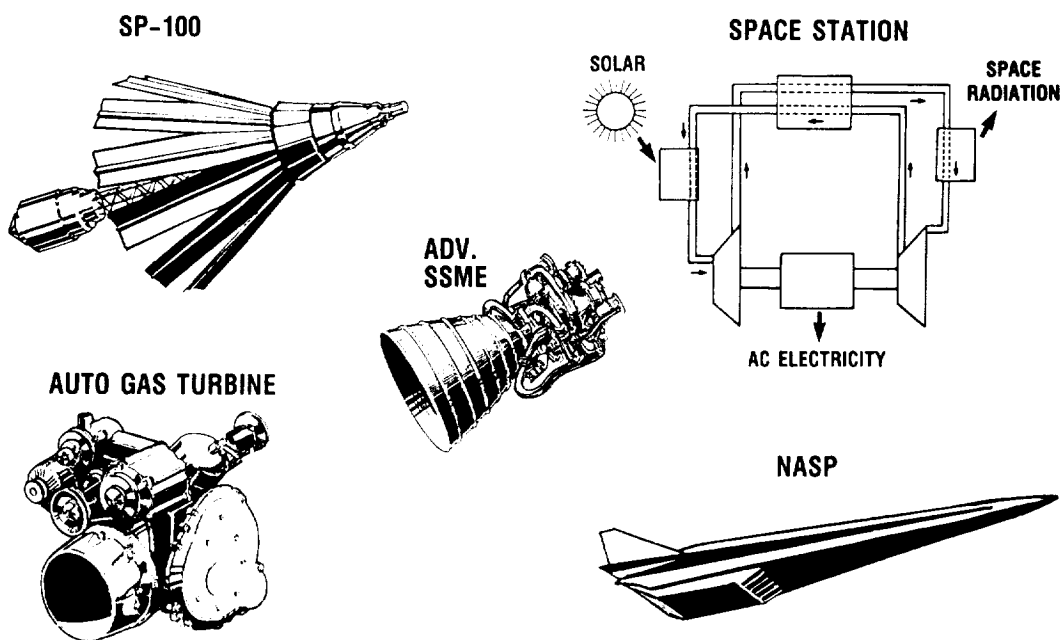
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Figure 4. - Basic research.



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Figure 5. - Focused research and technology.



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Figure 6. - Systems support.

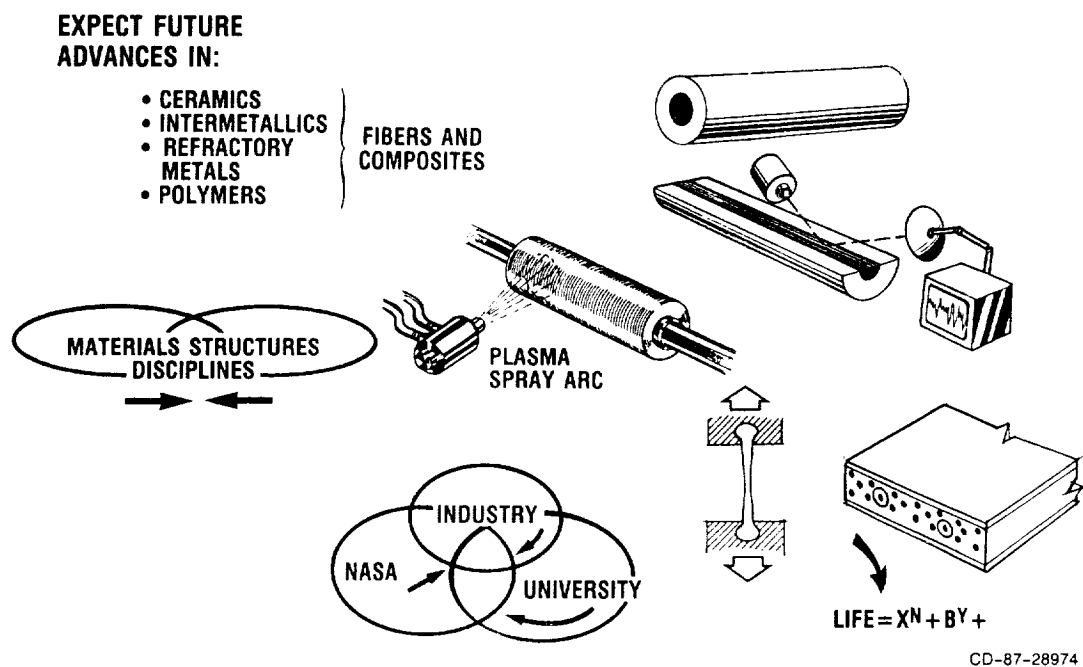


Figure 7. - The Advanced High-Temperature Engine Materials Technology Project 1988 to 1993.